

Technical Paper 112

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

JOSEPH A. HOLMES, DIRECTOR

THE EXPLOSIBILITY OF ACETYLENE

BY

GEORGE A. BURRELL

AND

G. G. OBERFELL



WASHINGTON
GOVERNMENT PRINTING OFFICE

1915

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines*. His is an entirely separate office and should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The cost of this publication is 5 cents.

First edition. July, 1915.

CONTENTS.

	Page.
Introduction.....	5
Comments on investigations of others.....	6
Bearing of conditions on results of experiments.....	6
Preparation of acetylene.....	7
Tests to determine low explosive limit of acetylene-air mixtures.....	7
Experiments to determine high explosive limit of acetylene-air mixtures.....	9
Liability of acetylene-air explosions in mines.....	10
Formation of acetylene from loose carbide.....	11
Explosibility of acetylene under pressure.....	11
Summary.....	12
Publications on mine accidents and methods of mining.....	12

THE EXPLOSIBILITY OF ACETYLENE.

By GEORGE A. BURRELL and G. G. OBERFELL.

INTRODUCTION.

In this report are shown the results of experiments made by the Bureau of Mines to determine the limits of complete propagation of flame in mixtures of acetylene and air.

The term "limits of complete propagation of flame" is used by the authors to designate the lowest and highest percentages of a combustible gas in mixture with air that permit combustion to spread through the mixture from any given point of ignition. Propagation of flame then takes place from point to point or layer to layer throughout the mixture without any necessity for the continued presence of the source of heat that starts the inflammation.

Acetylene is used extensively as an illuminant in miners' lamps. For this reason and because of the ease of generation of the gas from water and calcium carbide it seemed desirable to present a study of the possibilities of explosions occurring when the carbide is being handled in mines. An additional reason lies in the different results obtained by different investigators in determining the inflammable limits of mixtures of acetylene and air, as is shown by the following table:

Inflammable limits of acetylene mixtures as determined by various investigators.

Name of investigator.	Low limit of acetylene content.	High limit of acetylene content.
	<i>Per cent.</i>	<i>Per cent.</i>
Teclu ^a	1.53 to 1.77	59.95 to 58.65
Bunte ^b	3.35	52.30
Clowes ^c	3.00	82.0
Le Chatelier ^d	2.8	65.0

^aTeclu, N., Zur Ermittlung von Explosionsgrenzen in Gasmengen (Contribution to the subject of the determination of explosive limits of gas mixtures): Jour. prakt. Chem., Bd. 75, 1907, pp. 212-223.

^bBunte, H., Über explosive Gasmengen (Explosive gas mixtures): Jour. Gasbel., Bd. 44, 45, 1901, pp. 835-842.

^cClowes, Frank, The limiting explosive proportions of acetylene and measuring the gas in the air: Jour. Soc. Chem. Ind., vol. 15, Oct. 31, 1896, p. 701.

^dLe Chatelier, H., Sur la combustion de l'acétylène (On the combustion of acetylene): Compt. rend., t. 121, 1895, pp. 1144-1147.

COMMENTS ON INVESTIGATIONS OF OTHERS.

Teclu conducted his experiments in a glass cylinder 14 mm. wide. A platinum spark gap was placed near the top. Teclu's results on the inflammable limits of various gases have been criticized by Burgess and Wheeler,^a by Coward and Brinsley,^b and by Parker.^c Parker thought that Teclu did not allow sufficient time for the gases to mix before sparking them. Bunte conducted his experiments in a burette of 19-mm. diameter over water. Ignition was effected by an electric spark. Clowes conducted his experiments in a glass cylinder 3 inches in diameter and closed at one end. Ignition was effected from above with a Bunsen flame.

Of much interest are further experiments performed by Le Chatelier^d on the propagation of flame in glass tubes of small diameter. The limits of inflammability for different sizes of tubes, as determined by Le Chatelier, are as follows:

Limits of inflammability of acetylene-air mixtures in tubes of different sizes.

Diameter of tube.	Proportion of acetylene for low limit.	Proportion of acetylene for high limit.
Mm.	Per cent.	Per cent.
0.5.....	7.7	10.0
.8.....	7.7	10.0
2.0.....	5.0	15.0
4.0.....	4.5	25.0
6.0.....	4.0	40.0
20.0.....	3.5	55.0
30.0.....	3.1	62.0
40.0.....	2.9	64.0

BEARING OF CONDITIONS ON RESULTS OF EXPERIMENTS.

Work by the authors and others on the limits of complete propagation of flame in mixtures of combustible gases and air has shown that the results obtained are much affected by the conditions of any given experiment. Differences obtained are due to (1) the use of vessels so small that they allow too great heat absorption by the containing walls, (2) differences in method of igniting the mixtures—whether from the bottom upward or from the top downward—(3) improper mixing and analysis of the gas mixtures, (4) to a lack of proper conception of the term “limit of complete inflammation,” and (5) because the distance traversed by the flame has not been sufficient to prove that it will travel indefinitely through the mixture

^a Burgess, J. M., and Wheeler, R. V., The lower limit of inflammation of mixtures of the paraffin hydrocarbons with air: Trans. Chem. Soc., 1911, vol. 99, pp. 2013-2030.

^b Coward, H. F., and Brinsley, Frank, The dilution limits of inflammability of gaseous mixtures: Jour. Chem. Soc., vol. 106, July, 1914, pp. 1859-1885.

^c Parker, Albert, The lower limits of inflammation of methane with mixtures of oxygen and nitrogen: Jour. Chem. Soc., vol. 105, April, 1914, p. 1002.

^d Le Chatelier, H., Sur la combustion de l'acétylène: Compt. rend., t. 121, 1895, pp. 1144-1147.

after its propagation has become independent of the initial impulse of the igniting arrangement. In the experiments reported herein the authors have endeavored to avoid the errors mentioned. The use of a large box of 130-liter capacity and 1 square foot cross section eliminated some of the most serious sources of error.

PREPARATION OF ACETYLENE.

Acetylene for the author's experiments was prepared by the action of water on calcium carbide such as is furnished miners for use in their acetylene lamps. Analyses were made as the various mixtures were prepared for experiment. The analytical data covering the analyses of one mixture of acetylene and air follow. The determination was made by igniting a measured quantity of the mixture with a hot platinum spiral.

Results of analyses of an acetylene-air mixture.

Item.	Analysis 1.	Analysis 2.
	C. c.	C. c.
Sample taken.....	49.90	50.10
Air added.....	0.00	9.90
Total volume for combustion.....	49.90	60.00
Volume after combustion.....	47.85	57.80
Contraction due to combustion.....	2.05	2.20
Volume after KOH absorption.....	45.10	55.00
Carbon dioxide produced by combustion.....	2.75	2.80
Proportion of acetylene (from carbon dioxide).....	a 2.76	a 2.80

a Per cent.

A part of the same sample was also analyzed by causing the acetylene to be absorbed in bromine water. By this method there was obtained 2.88 per cent acetylene, a good check on the combustion method of determining the acetylene.

TESTS TO DETERMINE LOW EXPLOSIVE LIMIT OF ACETYLENE-AIR MIXTURES.

The results of tests made to determine the low limit of complete inflammation in a Hempel glass explosion pipette follow. The pipette was spherical and had a capacity of 100 c. c. Entering near the top were two platinum wires, across which a spark could be passed from an induction coil driven by dry cells.

Results of experiments to determine low limit of complete propagation of ignition in acetylene-air mixtures in the Hempel pipette.

Test No.	Proportion of acetylene.	Result of observation.
	Per cent.	
1.....	2.78	No visible effect.
2.....	2.82	Do.
3.....	3.00	Complete inflammation.
4.....	3.19	Do.

From the above tests there was found as the low limit a value between 2.82 and 3.00 per cent acetylene.

The products of combustion after each test were analyzed. The carbon dioxide resulting from test 1 was only 0.20 per cent of the mixture. The carbon dioxide after test 2 was 0.25 per cent. The carbon dioxide after test 3 was 5.79 per cent, equivalent to 2.90 per cent acetylene, showing that practically all the acetylene burned to carbon dioxide and water. The carbon dioxide after test 4 was 6.11 per cent, corresponding to 3.06 per cent acetylene.

The low limit was next investigated in a larger explosion vessel. The vessel had a capacity of 2,800 c. c. Two copper wires entered through the sides and met in the center of the vessel. A current of 5 amperes at 220 volts was passed through the wires. Ignition of acetylene-air mixtures inside the jar was brought about by drawing the two wires apart while the electric current was flowing, thereby producing an electric spark. The results of the tests were as follows:

Results of tests to determine low limit of mixtures of acetylene and air in an explosion vessel of 2,800-c. c. capacity.

Test No.	Proportion of acetylene.	Results of observations.
	<i>Per cent.</i>	
1.....	2.81	Incomplete inflammation. Flame traveled for 1 to 2 inches above the terminals, but did not spread throughout the mixture.
2.....	2.98	Do.
3.....	3.07	Complete inflammation. Flame spread throughout the mixture.

The experiments showed that complete propagation of flame was obtained when the proportion of acetylene was between 2.98 and 3.07 per cent.

Experiments on the low limit were next made with a box made of glass and wood, having a capacity of 130 liters and a cross section of 1 square foot. The front and rear of the box were made of glass, so that the propagation of flame, when this occurred, could be observed. A motor-driven fan at the bottom of the box mixed the gases. A sheet of paper was used to cover the top of the box. The source of ignition was an electric flash produced by drawing two copper wires apart, as in the preceding tests. Ignition was started both at the top and the bottom of the box. The results of the experiments follow.

Results of experiments to determine low limit of mixtures of acetylene and air contained in a 130-liter box.

IGNITION FROM BOTTOM UPWARD.

Test No.	Proportion of acetylene.	Remarks.
	<i>Per cent.</i>	
1.....	2.42	A flame about 1 inch wide traveled 2 inches above the source of ignition.
2.....	2.42	Do.
3.....	2.50	A flame about 1 inch wide traveled 1 foot above the source of ignition.
4.....	2.50	Do.
5.....	2.53	The flame traveled to the top of the box.
6.....	2.53	Do.
7.....	2.67	Do.
8.....	2.73	Do.

IGNITION FROM TOP DOWNWARD.

1.....	2.52	The flame did not travel downward.
2.....	2.62	Do.
3.....	2.68	Flame traveled 1½ feet downward.
4.....	2.87	Flame traveled downward the length of the box.
5.....	3.11	Do.

The results of the foregoing experiments show that the complete propagation of flame was obtained upward through the box with a mixture containing 2.53 per cent acetylene. Propagation downwards was not obtained with less than 2.87 per cent acetylene.

EXPERIMENTS TO DETERMINE HIGH EXPLOSIVE LIMIT OF ACETYLENE-AIR MIXTURES.

Experiments were also performed having to do with the high limit of acetylene-air mixtures. The results of experiments made in the Hempel explosion pipette follow:

Results of experiments to determine high limit of complete propagation of flame in acetylene-air mixtures in Hempel pipette.

Test No.	Proportion of acetylene.	Remarks.
	<i>Per cent.</i>	
1.....	58.66	No observed effect, except small deposit of carbon near terminals.
2.....	56.44	Do.
3.....	55.14	Do.
4.....	54.14	Do.
5.....	53.42	Do.
6.....	52.63	Do.
7.....	51.72	Do.
8.....	50.00	Complete inflammation with a heavy deposit of carbon all over inside of pipette.
9.....	49.53	Do.

The experiments showed that under the conditions the high limit of complete propagation of flame of acetylene-air mixtures was between 50 and 51.72 per cent acetylene.

Further experiments were performed on the high limit, with the 2,800-c. c. vessel. The copper wires carrying the current met at a

point close to the bottom of the jar, so that inflammation could be originated at the bottom of the mixture. The results follow:

Results of experiments to determine upper limit of complete inflammation of acetylene-air mixtures, with a current of 5 amperes at 220-volt pressure as the source of ignition.

Proportion of acetylene.	Remarks.
<i>Per cent.</i>	
51.3.....	Complete propagation of flame.
52.4.....	Do.
53.4.....	Do.
59.5.....	Do.
63.5.....	Do.
73.0.....	Do.
75.2.....	Narrow flame traveled to top and was extinguished. When the electric flash was applied for a second time, complete propagation with a loud report followed.
76.3.....	Narrow band of flame traveled to top of jar. Did not spread to sides.
77.1.....	No propagation of flame. Slight inflammation around terminals of wire.
78.3.....	Do.

Under the different conditions of the experiments widely different results were obtained. With the Hempel pipette, an upper limit close to 50 per cent acetylene was found, and with the 2,800-c. c. vessel an upper limit close to 73 per cent was established. It seems, then, that the upper limit is much affected by the conditions of experiment, a fact that probably explains why widely different results have been obtained by different investigators. The wooden box used in some of the preceding tests was not considered strong enough to withstand the explosion of large percentages of acetylene, and therefore was not used to determine the upper limit of acetylene-air mixtures.

LIABILITY OF ACETYLENE-AIR EXPLOSIONS IN MINES.

With the increasing use of acetylene in mines, there has arisen the question of the danger of its exploding in the mine from various causes. There may first be considered the quantity of calcium carbide necessary to furnish explosive proportions of acetylene. Four and six-tenths (4.6) cubic feet of acetylene from 1 pound of calcium carbide may be considered a good yield. Four and six-tenths cubic feet of gas would render 182 cubic feet ^a of air explosive on the basis of the low explosive limit of acetylene-air mixtures being 2.53 per cent acetylene under the ideal condition that the acetylene be uniformly mixed throughout such a space, and confined to it. Such an accident as the dropping of calcium carbide in a pool of water on the floor would result in a rich mixture near the water, the mixture gradually becoming leaner, of course, as the acetylene diffused into the air or was swept away by the ventilating current of

^a One hundred and eighty-two (182) cubic feet of air would be contained in a room 6 feet wide, 6 feet high, and about 5 feet long.

the mine. The ignition of acetylene produced under such conditions would result in the formation of a flame confined to a much smaller space than the dimensions given.

The calcium carbide in a miner's lamp (about 50 grams), upon contact with water, would produce 0.51 cubic foot of gas. This quantity could render about 21 cubic feet of air explosive if the acetylene could be confined to a space of that size. However, such a condition is not probable.

FORMATION OF ACETYLENE FROM LOOSE CARBIDE.

There remains to be considered the formation of acetylene from the action of the moisture in the mine air on calcium carbide that might be thrown on the floor of the mine. A room 18 feet wide by 30 feet long by 7 feet high would contain 3,780 cubic feet of air. In this space, if the temperature was 65° F. and the saturation 90 per cent, there would be contained 1,495 grams of water. One thousand four hundred and ninety-five (1,495) grams of water would be enough for complete reaction with 2,660 grams of calcium carbide and would produce about 27.0 cubic feet of acetylene. The production of acetylene in this manner would be too slow, however, to form an explosive mixture with air, because the acetylene first formed would be continuously carried away by diffusion and air currents, and consequently there would not result the accumulation necessary to form an explosive mixture.

On the whole, with reasonable precaution, there need be little danger from explosion of acetylene in mines. That such an explosion may happen, however, is shown by a coal-mine accident, the details of which were as follows: A miner carrying calcium carbide in a glass bottle stumbled and fell. The bottle broke, throwing the carbide into some water on the floor. Acetylene was immediately generated and was ignited by the miner's cap light, severely burning him. Such an accident is a rarity.

EXPLOSIBILITY OF ACETYLENE UNDER PRESSURE.

Several experiments were made in order to determine the effect of pressure on the explosibility of pure acetylene, as follows:

Acetylene, not mixed with air, was inclosed over mercury in a 100 c. c. glass vessel and its pressure slowly increased by means of a column of mercury until a maximum of 5 atmospheres pressure was obtained. No explosion resulted. The experiment was twice repeated, and each time under a pressure of 5 atmospheres a mild explosion with the formation of much carbon resulted when a platinum coil in the gas was electrically heated to a white heat.

Under the same conditions of experimentation, except that a small electric spark from an induction coil was used as the source of ignition, the gas exploded with great violence at a pressure of 3 atmospheres.

Experiments were then made to determine the effect of increased initial pressure on the low explosive limit of acetylene-air mixtures. It was found that with an initial pressure of as much as 5 atmospheres the low limit obtained, between 2.82 and 3 per cent acetylene (ignition from the top) is not different from the value obtained with an initial pressure of 1 atmosphere.

When acetylene was mixed with air so as to form 10, 20, 30, 40, 50, 60, 70, 80, and 90 per cent acetylene mixtures no explosion resulted from compressing the mixtures to 1, 2, 3, 4, and 5 atmospheres. No means of ignition, such as an electric spark or a heated platinum wire, was used.

SUMMARY.

The authors' experiments showed that the smallest proportion of acetylene capable of propagating flame in a mixture of acetylene and air was 2.53 per cent.

The largest proportion of acetylene capable of propagating flame in a mixture of acetylene and air was found to be about 73 per cent.

Acetylene, not mixed with air, is explosive under a pressure of 3 to 5 atmospheres when an electric spark is passed through the mixture or when a platinum spiral is heated in it.

The danger connected with the handling of calcium carbide in a mine is remote if reasonable care is observed in handling.

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF MINING.

Limited editions of the following Bureau of Mines publications are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should select only those publications that are of especial interest to them. All requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1913. 50 pp., 3 pls., 7 figs.

BULLETIN 50. A laboratory study of the inflammability of coal dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr. 1913. 60 pp., 95 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 170 pp., 16 pls., 12 figs.

BULLETIN 56. First series of coal-dust explosion tests in the experimental mine, by G. S. Rice, L. M. Jones, J. K. Clement, and W. L. Egy. 1913. 115 pp., 12 pls., 28 figs.

BULLETIN 60. Hydraulic mine filling; its use in the Pennsylvania anthracite fields; a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

BULLETIN 62. National mine-rescue and first-aid conference, Pittsburgh, Pa., September 23-26, 1912, by H. M. Wilson. 1913. 74 pp.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 40 pp., 6 pls.

BULLETIN 69. Coal-mine accidents in the United States and foreign countries, compiled by F. W. Horton. 1913. 102 pp., 3 pls., 40 figs.

BULLETIN 80. A primer on explosives for metal miners and quarrymen, by C. E. Munroe and Clarence Hall. 1915. 125 pp., 15 pls., 17 figs.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 6. The rate of burning of fues as influenced by temperature and pressure, by W. O. Snelling and W. C. Cope. 1912. 28 pp.

TECHNICAL PAPER 7. Investigations of fuse and miners' squibs, by Clarence Hall and S. P. Howell. 1912. 19 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 14. Apparatus for gas-analysis laboratories at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

TECHNICAL PAPER 15. An electrolytic method of preventing corrosion of iron and steel, by J. K. Clement and L. V. Walker. 1913. 19 pp., 10 figs.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

TECHNICAL PAPER 18. Magazines and thaw houses for explosives, by Clarence Hall and S. P. Howell. 1912. 34 pp., 1 pl., 5 figs.

TECHNICAL PAPER 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions; report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 12 pp. Reprint of United States Geological Survey Bulletin 369.

TECHNICAL PAPER 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

TECHNICAL PAPER 24. Mine fires, a preliminary study, by G. S. Rice. 1912. 51 pp., 1 fig.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp.

TECHNICAL PAPER 29. Training with mine-rescue breathing apparatus, by J. W. Paul. 1912. 16 pp.

- TECHNICAL PAPER 30. Mine-accident prevention at Lake Superior iron mines, by D. E. Woodbridge. 1913. 38 pp., 9 figs.
- TECHNICAL PAPER 39. The inflammable gases in mine air, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 2 figs.
- TECHNICAL PAPER 40. Metal-mine accidents in the United States during the calendar year 1911, compiled by A. H. Fay. 1913. 54 pp.
- TECHNICAL PAPER 43. The effect of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.
- TECHNICAL PAPER 44. Safety electric switches for mines, by H. H. Clark, 1913. 8 pp.
- TECHNICAL PAPER 47. Portable electric mine lamps, by H. H. Clark. 1913. 13 pp.
- TECHNICAL PAPER 48. Coal-mine accidents in the United States, 1896-1912, with monthly statistics for 1912, compiled by F. W. Horton. 1913. 74 pp., 10 figs.
- TECHNICAL PAPER 52. Permissible explosives tested prior to March 1, 1913, by Clarence Hall. 1913. 11 pp.
- TECHNICAL PAPER 58. The action of acid mine water on the insulation of electric conductors; a preliminary report, by H. H. Clark and L. C. Ilsley. 1913. 26 pp., 1 fig.
- TECHNICAL PAPER 59. Fires in Lake Superior iron mines, by Edwin Higgins. 1913. 34 pp., 2 pls.
- TECHNICAL PAPER 69. Production of explosives in the United States during the calendar year 1912, compiled by A. H. Fay. 1914. 8 pp.
- TECHNICAL PAPER 71. Permissible explosives tested prior to January 1, 1914, by Clarence Hall. 1914. 12 pp.
- TECHNICAL PAPER 75. Permissible electric lamps for miners, by H. H. Clark. 1914. 21 pp., 3 figs.
- TECHNICAL PAPER 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.
- TECHNICAL PAPER 77. Report of the Committee on Resuscitation from Mine Gases, by W. B. Cannon, George W. Crile, Joseph Erlanger, Yandell Henderson, and S. T. Meltzer. 1914. 36 pp., 4 figs.
- TECHNICAL PAPER 78. Specific-gravity separation applied to the analysis of mining explosives, by C. G. Storm and A. L. Hyde. 1914. 13 pp.
- TECHNICAL PAPER 85. Production of explosives in the United States during the calendar year 1913, compiled by A. H. Fay. 1914. 15 pp.
- TECHNICAL PAPER 92. Quarry accidents in the United States during the calendar year 1913, compiled by A. H. Fay. 1914. 73 pp.
- TECHNICAL PAPER 94. Metal-mine accidents in the United States during the calendar year 1913, compiled by A. H. Fay. 1914. 73 pp.
- MINERS' CIRCULAR 3. Coal-dust explosions, by G. S. Rice. 1911. 22 pp.
- MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.
- MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.
- MINERS' CIRCULAR 7. Use and misuse of explosives in coal mining, by J. J. Rutledge. 1914. 51 pp., 8 figs.
- MINERS' CIRCULAR 8. First-aid instructions for miners, by M. W. Glasgow, W. A. Raudenbush, and C. O. Roberts. 1913. 67 pp., 51 figs.
- MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.
- MINERS' CIRCULAR 12. Use and care of miners' safety lamps, by J. W. Paul. 1913. 16 pp., 4 figs.

MINERS' CIRCULAR 13. Safety in tunneling, by D. W. Brunton and J. A. Davis. 1913. 19 pp.

MINERS' CIRCULAR 14. Gases found in coal mines, by G. A. Burrell and F. M. Seibert. 1914. 23 pp.

MINERS' CIRCULAR 15. Rules for mine-rescue and first-aid field contests, by J. W. Paul. 1913. 12 pp.

MINERS' CIRCULAR 16. Hints on coal-mine ventilation, by J. J. Rutledge. 1914. 22 pp.

MINERS' CIRCULAR 21. What a miner can do to prevent explosions of gas and coal dust, by G. S. Rice. 1915. 24 pp.

